DOCUMENT RESUME

ED 177 121 SP 014 611

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TITLE Running Patterns of Highly Skilled Distance Runners.
PUB DATE Mar 79
NOTE 22p.; Paper presented at the AAHPER National Convention (New Orleans, Louisiana, March 1979)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Athletics; *Biomechanics; Comparative Testing; Efficiency; Individual Characteristics; *Individual Differences; *Individualized Programs; *Norms; *Performance Factors; Physiology; *Running

ABSTRACT

The biomechanical elements inherent in the running styles of Olympic-level athletes were examined in order to obtain a range of parameter values for specific running velocities. Forty-eight athletes participated in middle and long distance running events that were filmed and later analyzed to determine the relationship between the physical components of each runner's style and that runner's track performance. Group norms were established for characteristics such as thrust angle, touchdown (to ground), angle relative to hip location, trunk angle, vertical rise, stride length, stride rate, leg length, times of support (by ground) and nonsupport, and horizontal velocity. This information was then arranged in chart form. Diagrams designed to elucidate the results were drawn, and suggestions for a theoretical model of running based on arithmetic stylemes were developed. (LH)

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ED177121

Running Patterns of Highly Skilled Distance Runners

by

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A research paper presented at
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March 1979

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Introduction

Although there have been numerous biomechanical studies of running, relatively little information is available as to whether or not baseline values can be established for specific running parameters. To date, most of the biomechanical studies have either described the running motion, tried to correlate one running parameter with another, or tried to investigate the change in a number of parameters with a change in velocity.

In the summer of 1978, a middle and long distance running camp was held at the University of Illinois on behalf of the U.S.O.C. The purpose of the camp was to provide the coaches and the athletes with relevant information on the physiological, biomechanical and psychological aspects of running. From the biomechanical point of view, the main objective was to obtain information about each athlete's running style and then present this information to the athletes and their coaches for their future use. A total of 48 athletes were present, 24 of which competed in 800m, 1500m events, 10 in 3000m s/c, and 14 in 5000 or 10,000m events. All the athletes were of Olympic or near Olympic standard. Thus, there was a good opportunity to try and establish some baseline values for specific running parameters.

The purpose of the study, therefore, was twofold; first, to provide biomechanical information about the running style of each athlete which might aid performance, and secondly to try and obtain a range of parameter values for specific running velocities.

Method

Filming of the athletes was carried out over a two day period at the University of Illinois. Athletes from 800m and 1500m events were filmed the first day and the second day was used to film the remaining from 3000m steeplechase, 5000m and 10,000m events. The results of the film analysis were presented to the athletes and coaches during the following two days.

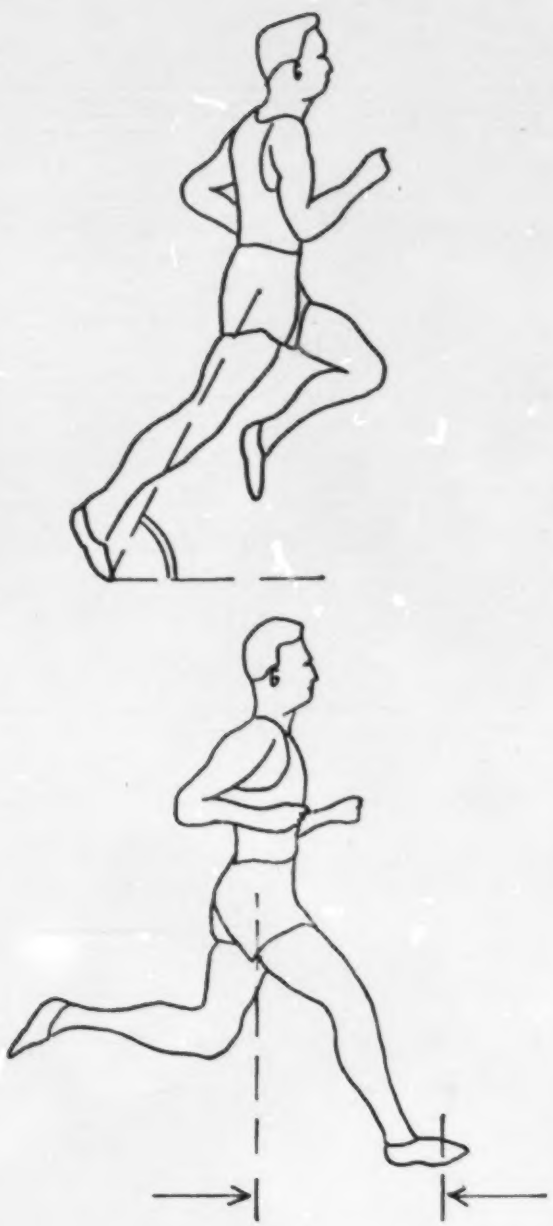
Standard biomechanical techniques were used for the filming; a 16mm high speed Locam camera was loaded with color film and run at 130 fps. In all cases, the athletes were filmed from the side as they ran over a 300m course.

Analysis

The film was analyzed using a Numonics Digitizer and Hewlett-Packard calculator. The parameters that were anlayzed were selected on the basis of their importance to the coaches and athletes for providing information about the running style, (fig. 1-Fig. 2).

Thrust Angle: angle of body projection as the toes of the take-off foot leave the ground. The angle is calculated with respect to the horizontal by a vector drawn from the toes of the take-off foot to the centre of gravity. The hip was selected to represent the centre of gravity because it was felt the coaches could readily identify with this point, rather than an abstract point such as the centre of gravity.

Touchdown relative to the centre of gravity: horizontal distance between the foot at touchdown and the centre of gravity (which is represented by the hip).



THRUST ANGLE

TOUCHDOWN RELATIVE TO
CENTER OF GRAVITY

FIGURE 1. RUNNING PARAMETERS

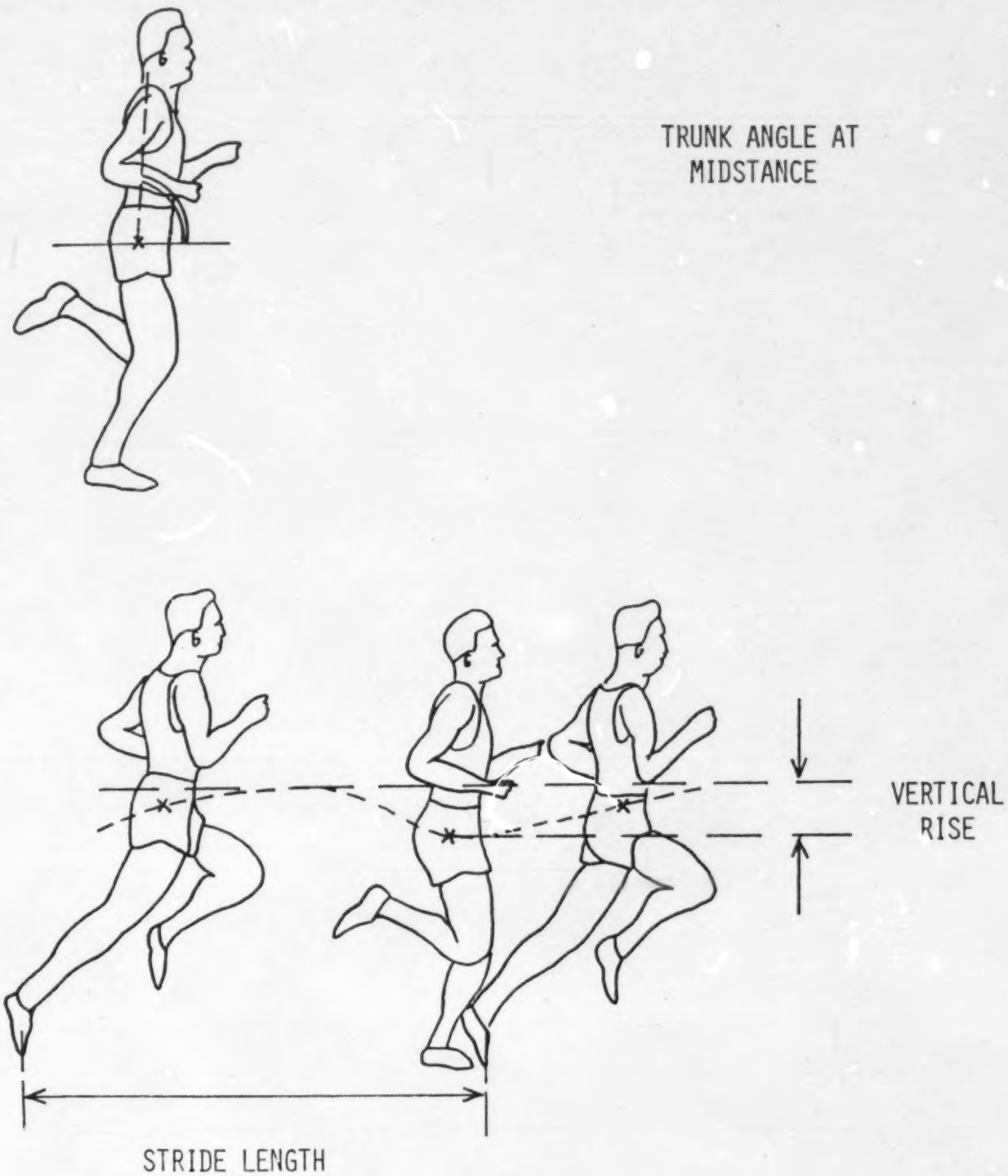


FIGURE 2. RUNNING PARAMETERS

Trunk angle at midstance: angle of the trunk when both knees are together.

Vertical rise: amount of vertical motion, or "bounce", exhibited by the body during one stride; that is, from toe-off of one foot to toe off of the other foot.

Stride length: horizontal distance from toe-off of one foot to toe-off of the opposite foot. This encompasses a period of flight followed by a period of support.

In addition to these parameters, five other biomechanical factors were measured; stride rate, time of support, time of non-support, horizontal velocity, the ratio stride length/leg length.

The ratio of stride length to leg length was used to try and indicate whether or not the athlete was overstriding. Leg length was measured from the greater trochanter of the femur to the malleolus of the fibula. A value significantly greater than the norm for this parameter would seem to indicate the athlete is overstriding.

After the above parameters had been determined for each athlete, group norms based on running velocity were constructed from the data. By comparing individual values with these norms, a picture of each athlete's running style was obtained. Since these athletes were very highly skilled and of a comparable standard, it was felt the construction of these norms would be useful in outlining the running styles. Parameter values lying more than one standard deviation from the norm might indicate a deficiency in the running style. However, it must be remembered that individual differences in running styles do exist. For this reason, these norms can only serve as guidelines and not absolutes. (Fig. 3).

Results

With the construction of group norms from the film analysis, it appears baseline values for specific running parameters can be established. Within each group of athletes, who are of a similar standard, some of the biomechanical

GROUP NORMS

PARAMETER	RUNNING VELOCITY 5.5-6.5 M/S		6.5-7.5 M/S		7.5-8.5 M/S	
PARAMETER	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
THRUST ANGLE (DEG)	57.444	± 1.928	57.791	± 2.241	57.315	± 2.018
TOUCHDOWN RELATIVE TO HIP (M)	0.397	0.039	0.393	0.045	0.368	0.053
TRUNK ANGLE (DEG)	80.548	2.933	80.004	2.329	80.617	2.858

FIGURE 3. GROUP NORMS

PARAMETERS	RUNNING VELOCITY					
	5.5-6.5 M/S		6.5-7.5 M/S		7.5-8.5 M/S	
PARAMETER	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARI DEVIATIC
VERTICAL RISE (M)	0.080	0.029	0.075	0.025	0.058	0.023
STRIDE LENGTH (M)	1.898	0.116	2.073	0.160	2.347	0.150
STRIDE RATE (STRIDES PER SECOND)	3.216	0.185	3.341	0.208	3.415	0.223
TIME OF SUPPORT (S)	0.179	0.013	0.159	0.013	0.140	0.012

FIGURE 3. GROUP NORMS
(CON'T)

PARAMETER	RUNNING VELOCITY					
	5.5-6.5 M/S		6.5-7.5 M/S		7.5-8.5 M/S	
PARAMETER	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARI DEVIATI(
TIME OF NON-SUPPORT (S)	0.133	0.017	0.152	0.016	0.154	0.013
HORIZONTAL VELOCITY (M/S)	6.098		6.902		7.99	
STRIDE LENGTH LEG LENGTH	2.218	0.138	2.319	0.168	2.566	0.135

FIGURE 3. GROUP NORMS
(CON'T)

data are quite consistent.

To determine the significance of some of the differences in the parameter values, a one way ANOVA with Scheffe's test for interaction was first carried out. Horizontal velocity was used as the dependent variable. The results of the analysis were as follows:

The change in thrust angle with velocity was not significant for any of the velocity groups. So it appears that the thrust angle stays around 75.5° no matter what the velocity of the athlete. (Fig. 4)

Touchdown relative to the hip changed significantly (α =0.10) between the slow (6 m/s) and fast (8m/s) velocity groups. Hence, it appears this distance remains fairly constant at slow velocities and only decreases when higher speeds are attained. (Fig.5)

The change in trunk angle was not significant at any level; thus, trunk angle appears to remain constant at about 80° for each velocity group (Fig.6).

There was a significant difference in vertical rise between the slow and fast velocity groups (α = 0.005). As running speed increases, therefore, the athlete's vertical excursion decreases; i.e. there is less 'bounce'. (Fig. 7).

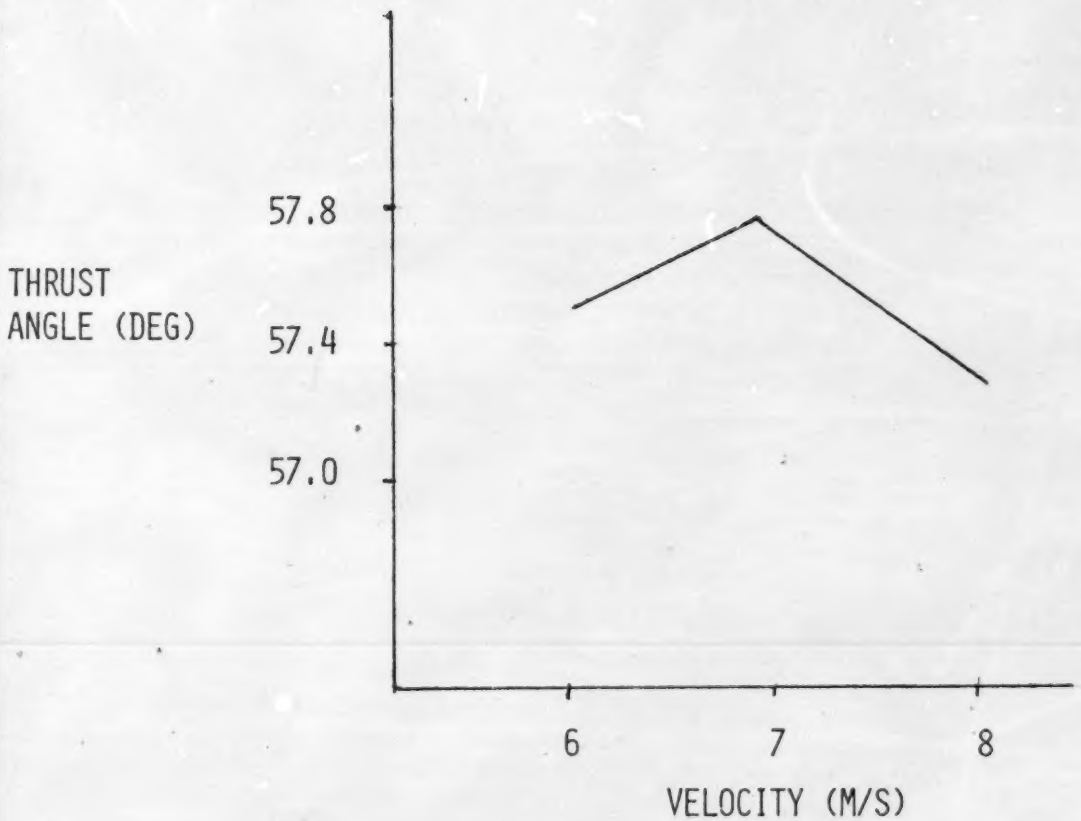
The change in stride length with velocity was significant across all three velocity groups (α = 0.001). Thus, as velocity increases, stride length increases also. (Fig. 8)

The change in stride rate was also significant across all three velocity groups (α = 0.001). As velocity increases, stride rate increases .

The change in time of support with velocity was significant across all three groups (α=0 0.001). As velocity increases, so time of support decreases (Fig. 10).

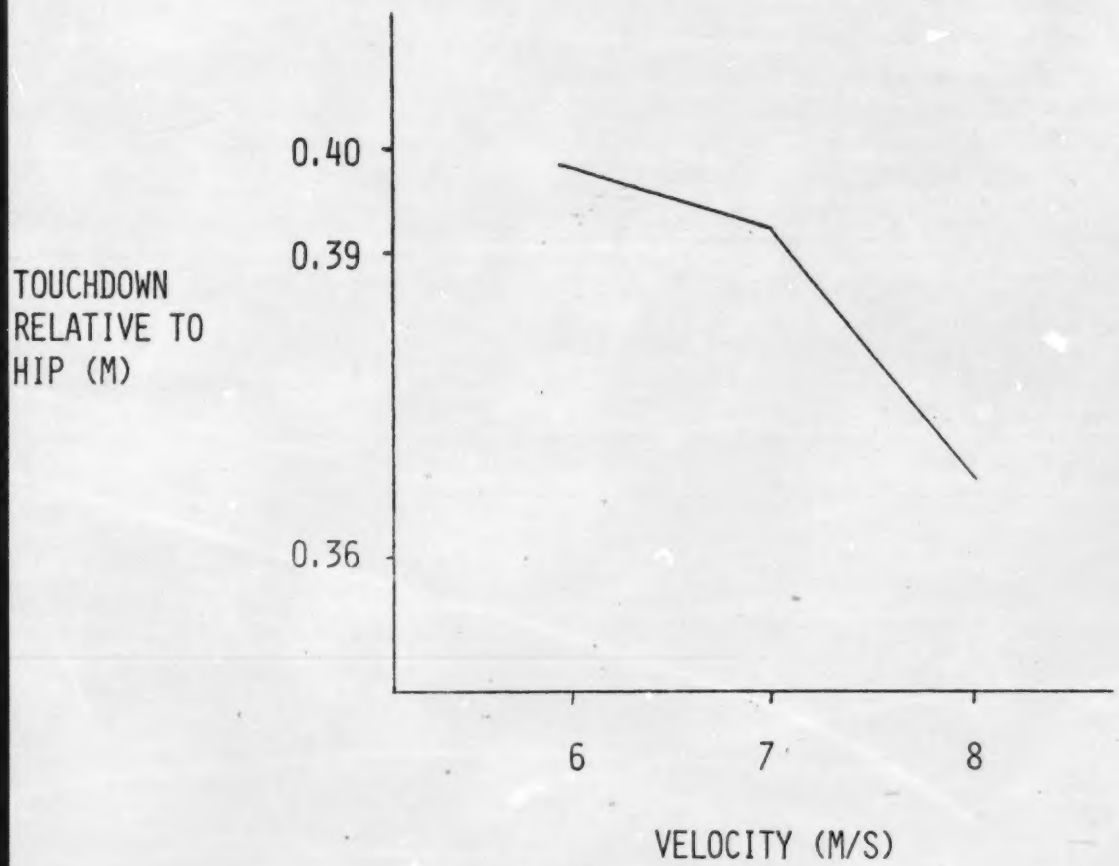
The change in time of non-support was significant at $\alpha = 0.005$ between the slow and medium group and the slow and fast velocity group. Thus, time of non-support initially increases with velocity, but then levels off. (Fig. 11).

The ratio stride length/leg length changed significantly with velocity as velocity increases, so this ratio increases. This is to be expected, since stride length also increased with velocity. (Fig. 12).



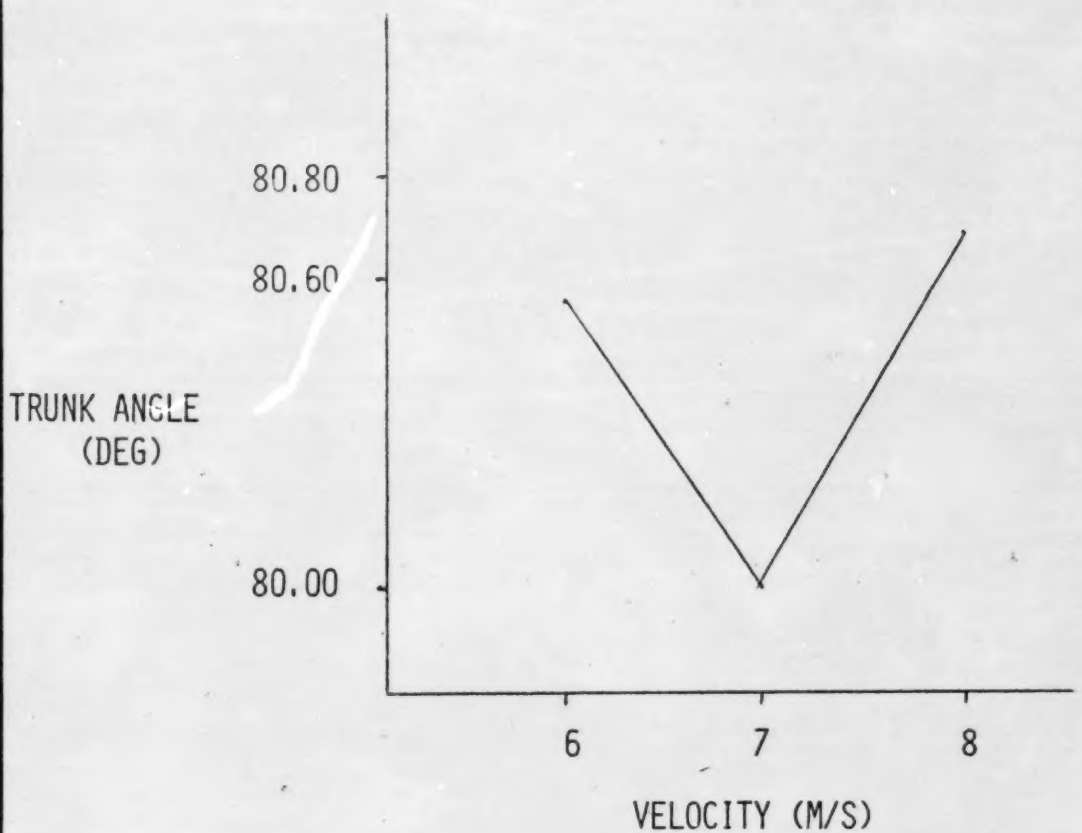
CHANGE IN THRUST ANGLE WITH VELOCITY

FIGURE 4



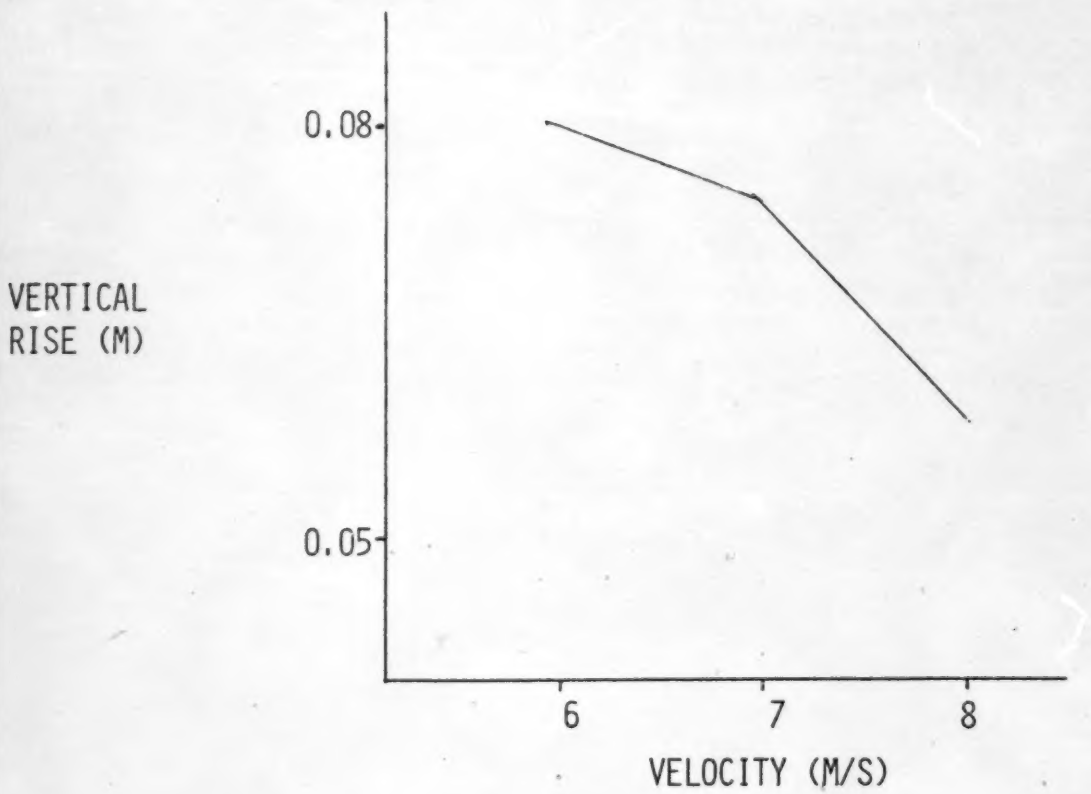
CHANGE IN TOUCHDOWN DISTANCE WITH VELOCITY

FIGURE 5



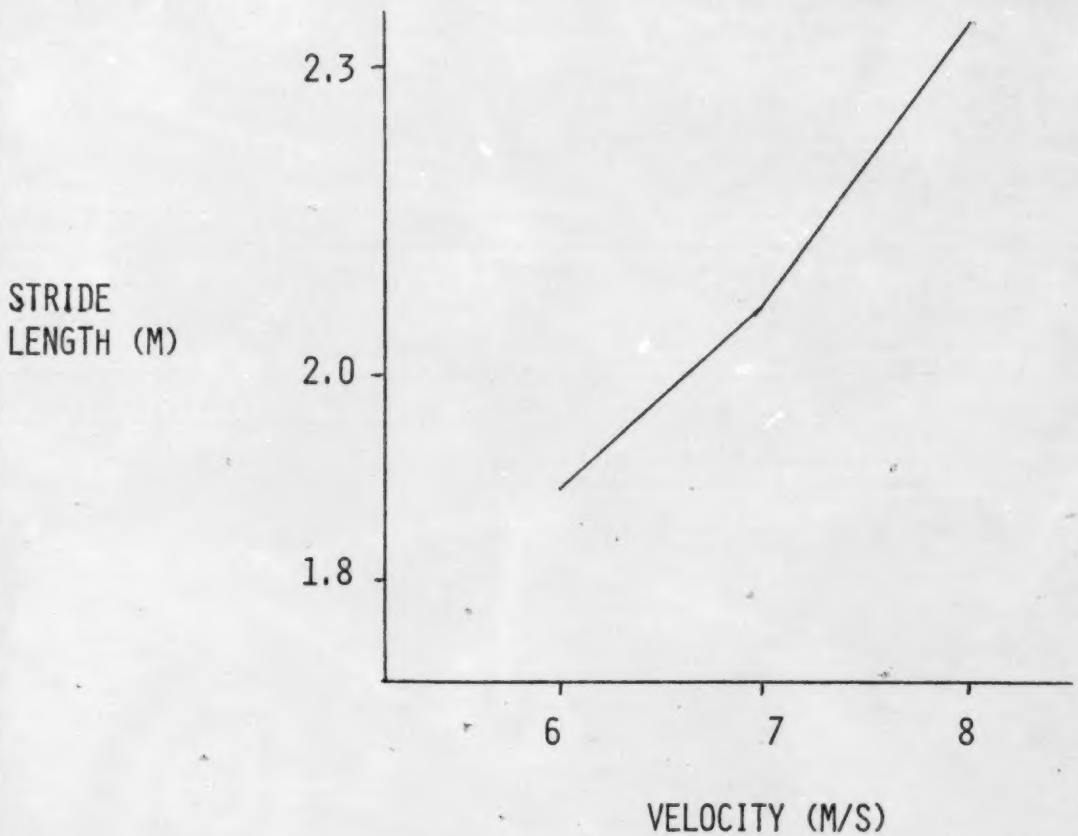
CHANGE IN TRUNK ANGLE WITH VELOCITY

FIGURE 6



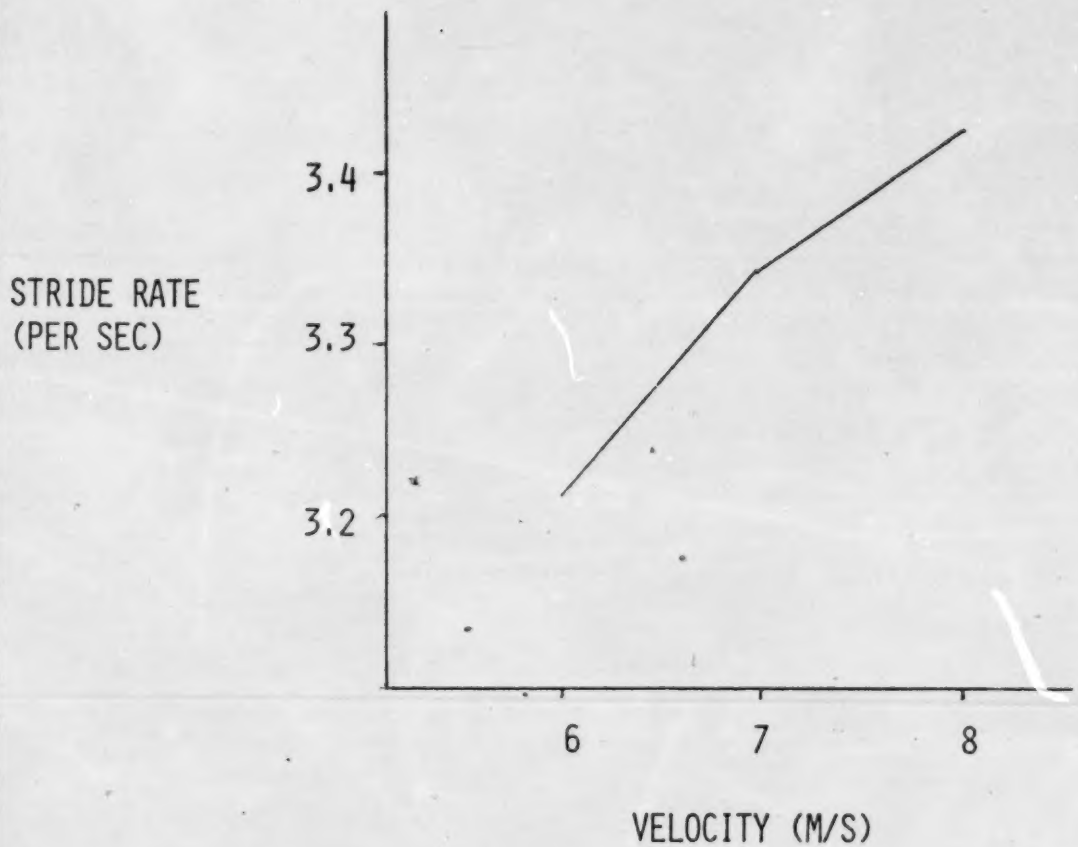
CHANGE IN VERTICAL RISE WITH VELOCITY

FIGURE 7



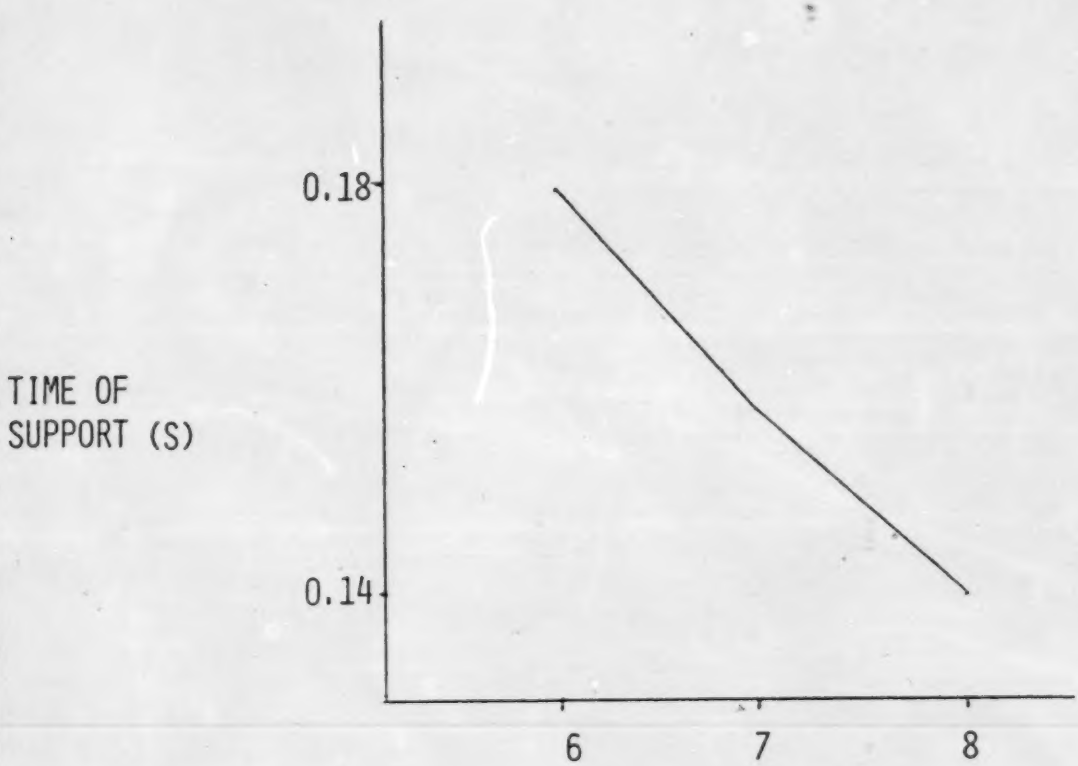
CHANGE IN STRIDE LENGTH WITH VELOCITY

FIGURE 8



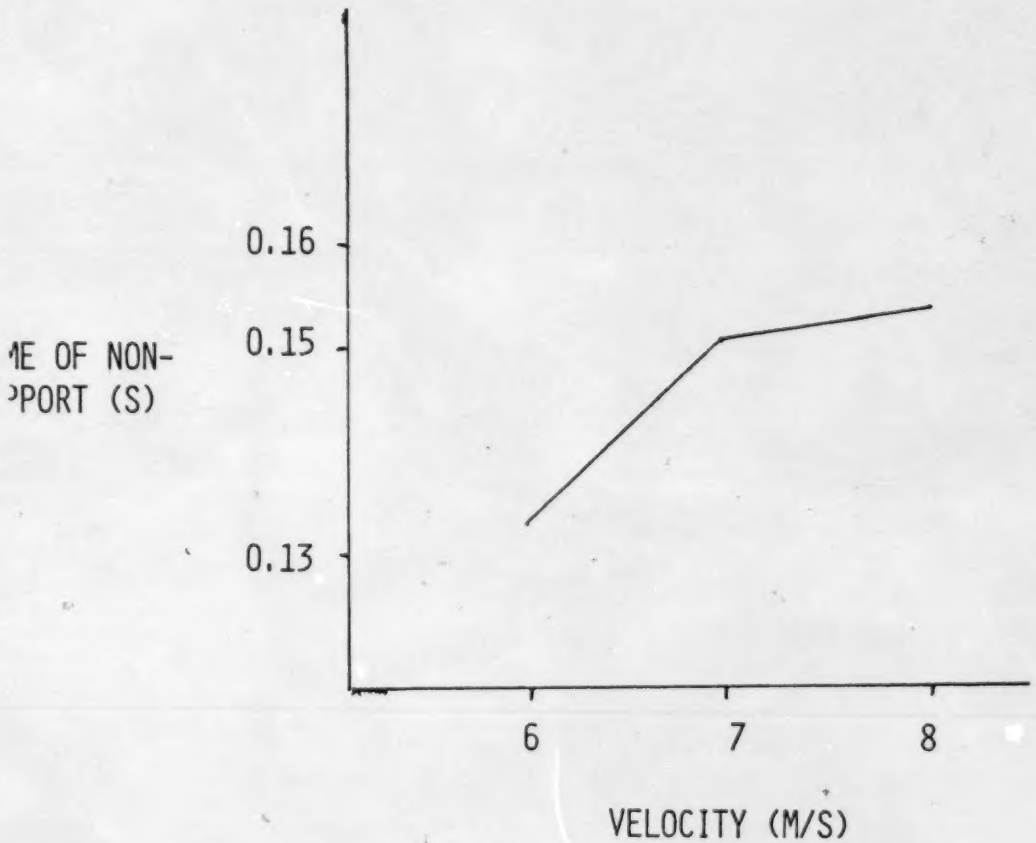
CHANGE IN STRIDE RATE WITH VELOCITY

FIGURE 9



CHANGE IN TIME OF SUPPORT WITH VELOCITY

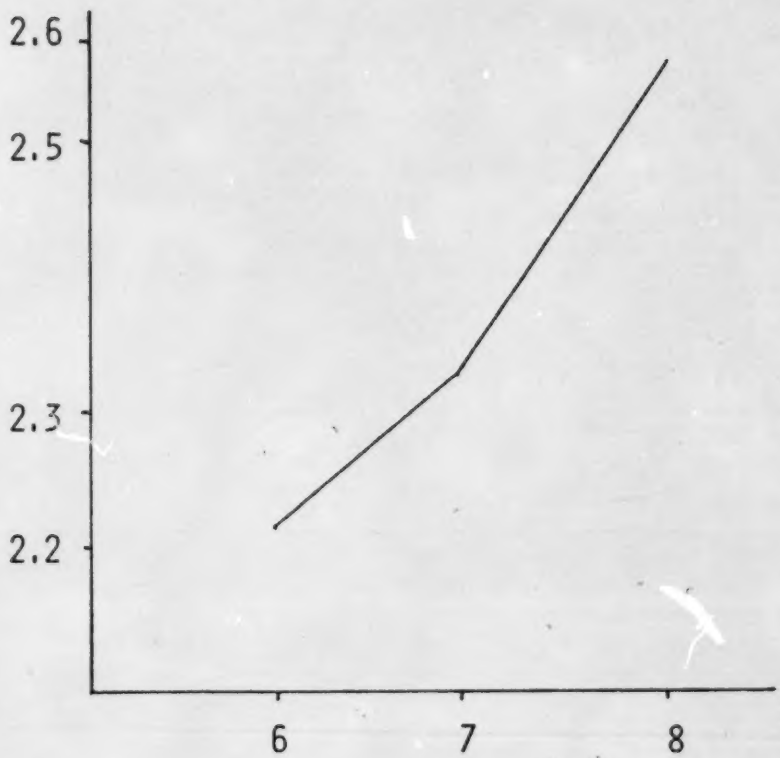
FIGURE 10



ME OF NON-
PPORT (S)

CHANGE IN TIME OF NON-SUPPORT WITH VELOCITY

FIGURE 11



CHANGE IN $\frac{\text{STRIDE LENGTH}}{\text{LEG LENGTH}}$ RATIO WITH VELOCITY

FIGURE 12

Conclusion

In conclusion, this study has attempted to obtain baseline values for specific running parameters. A correlation analysis between running parameters and horizontal velocity revealed stride length, stride rate, time of support and the ratio stride length/leg length had a high positive correlation with velocity. While time of support and vertical rise had a high negative correlation with velocity.

If baseline values can be established for the entire velocity range, it should be possible to construct a theoretical model of running. Once this has been done, an athlete can be compared to this model and any inefficiencies in his running style should become apparent. With the correction of these inefficiencies, performance should be improved.

This study has attempted to test the feasability of producing such a model. It does not take into account individual differences, which can and do play a large part in determining the success of an athlete. For this reason, the values of each of the running parameters can only serve as guidelines; they are not intended to be absolute values. Further study is necessary, both to establish parameter values across the whole running velocity range and to test the resulting model in real life situations.